IV. EMISSIONS, POTENTIAL EXPOSURES, AND RISK

This chapter presents the most recent emissions inventory for diesel-fueled ocean-going vessel auxiliary engines operating offshore of California as well as at California's ports. A discussion on the potential cancer and non-cancer health risks that may occur due to the operation of auxiliary engines is also provided.

A. Estimated Emissions from Ocean-going Vessel Auxiliary Engines

To develop an emissions estimate of the emissions from diesel-fueled ocean-going vessel auxiliary engines operating offshore of California as well as at California's ports, ARB staff developed a methodology that integrated information from three main sources of information:

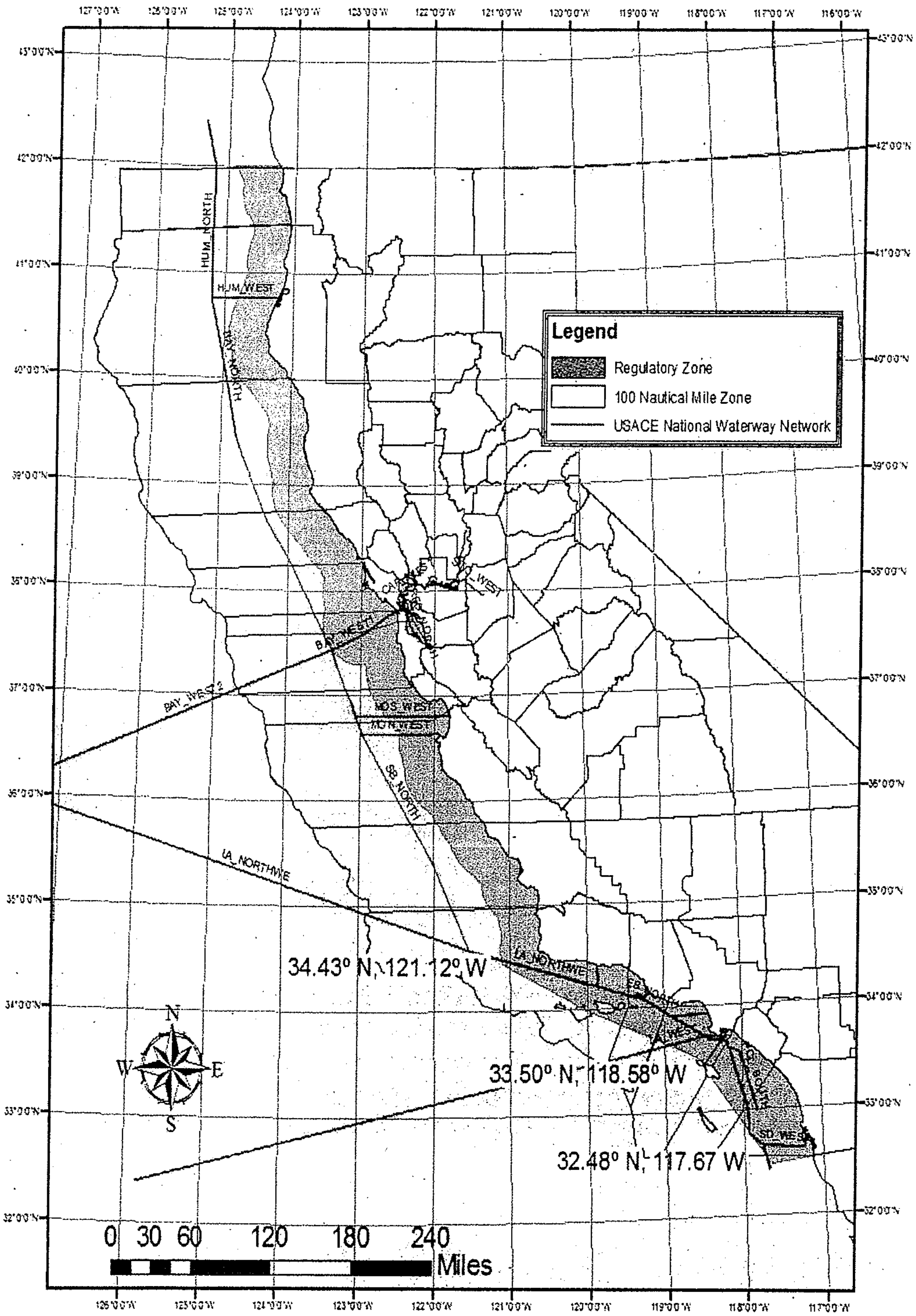
- ARB's 2005 Ocean-going Vessel Survey;
- 2004 California State Lands Commission ocean-going vessel visit data; and
- the ocean-going vessel element of the 2001 Port of Los Angeles emission inventory.

Baseline emission estimates for the year 2004 were developed and emission projections to 2010 and 2020 were also developed using estimates of expected growth. Details of the methodology are found in Appendix D. Based on the information available to date, we believe the methodology has resulted in a reasonable estimate of the emissions from ocean-going vessel auxiliary engines. However, there are continuing efforts by ARB and the major California ports to update and improve the ocean-going vessel emission inventories. As new information becomes available from these efforts, the ocean-going vessel auxiliary engine emission inventory will be updated.

Current 2004 Emission Estimates for Diesel-fueled Ocean-going Auxiliary Engines

ARB staff estimate that the statewide operation of diesel-fueled ocean-going vessel auxiliary engines operating 100 nm or less off of California's coast, in California's ports, and inland waters results in approximately 4 tons per day or approximately 1,430 tons per year of diesel PM emissions. These emission estimates are associated with the use of an ocean-going vessel's auxiliary engines to assist the propulsion engines during the maneuvering of the vessel or to power the vessels electrical systems while at dockside (hotelling). The estimates also include emissions from ocean-going vessels powered by diesel-electric engines. The emission estimation "boundary" of 100 nm was selected because it can be distinguished with relative ease and it is inclusive of the major areas of activity of the sources of interest. Figure IV-1 provides a graphical representation of the 100 nm emission inventory boundary. On the figure, the outer black line, which mirrors the California coastline, represents the inventory boundary while the shaded gray area is the region in which the proposed regulation would be applicable.

Figure IV-1: Ocean-going Vessel Emission Inventory Boundary



In addition, based on a range of statewide NOx to PM conversion factors of 0.3 – 0.5 g NH_4NO_3/g NOx, ARB staff estimate a secondary formation of PM_{10} nitrate from NOx emissions from ocean-going vessel diesel-fueled auxiliary engines to be between 13.1 and 21.8 tons per day.[2] This estimate only reflects the potential conversion of the ocean-going vessel auxiliary engine NOx emissions associated with maneuvering and hotelling activities. The ARB staff is unable at this time to adequately evaluate the potential for the formation of secondary PM_{10} nitrate at sea due to a lack of documentation concerning the impacts of higher humidity at sea, less available ammonia at sea, and the overall deposition of PM in transport along the coast of California. Because of this we believe these values are an underestimate of the quantities of secondary PM_{10} nitrate formed from ocean-going vessel diesel-fueled auxiliary engines.

Estimates of statewide 2004 diesel PM, NOx, SOx, carbon monoxide, and hydrocarbons from ocean-going vessel auxiliary engines are presented in Table IV-1.

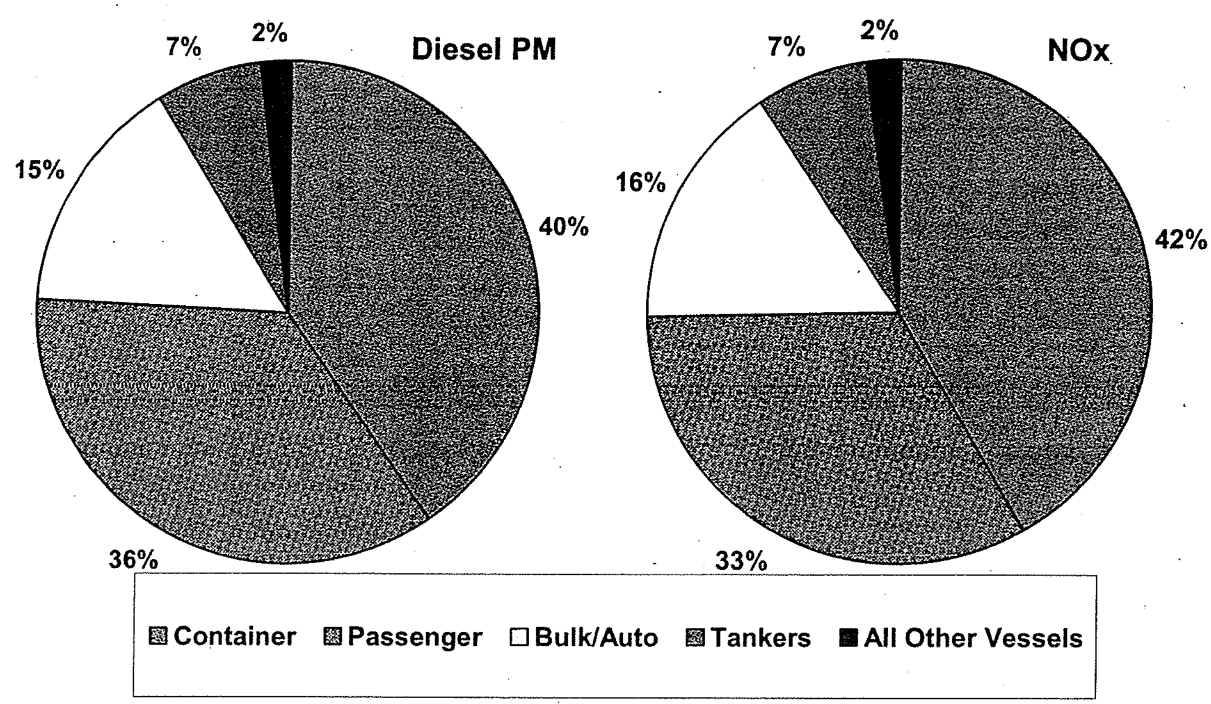
Table IV-1: Estimated Statewide 2004 Ocean-going Vessel Auxiliary Engine Emissions

Vessel Types	Numbers of Vessels	Numbers of Vessel Visits	2004 Pollutant Emissions, Tons/Day				
			NOx	HC	CO	PM	SOx
Auto	225	750	1.11	0.03	0.08	0.10	0.71
Bulk	475	946	4.02	0.11	0.30	0.35	2.55
Container	594	4744	18.11	0.50	1.37	1.57	11.48
General	196	721	1.75	0.05	0.13	0.15	1.11
Passenger	44	687	14.44	0.39	1.09	1.39	10.24
Reefer	19	52	0.60	0.02	0.05	0.05	0.38
RoRo	13	34	0.40	0.01	0.03	0.03	0.25
Tanker	372	1941	3.16	0.09	0.24	0.27	2.00
Totals	1938	9875	43.6	1.20	3.29	3.91	28.7

As shown in Table IV-1, there are approximately 1,900 ocean-going vessels that visited California's ports in 2004. Of those 1,900 vessels that visited California's ports, 30 percent were container vessels. Those container vessels represented more than 45 percent of the vessel visits to California's ports. As shown in Figure IV-2, container vessels represent approximately 50 percent of all the pollutants emitted by ocean-going vessel auxiliary engines; followed by passenger vessels, tankers, and bulk cargo and auto carriers.

[2] The conversion factor for the transformation of NOx to NH_4NO_3 was based on an analysis of annual-average conversion factors for secondary formation of PM_{10} nitrate from NOx emissions at a number of urban sites in California. A more detailed description of the methodology used to evaluate the conversion of NOx to NH_4NO_3 is found in Appendix E.

Figure IV-2: 2004 NOx and Diesel PM Emission Distributions for Ocean-going Vessel Auxiliary Engines



The ARB staff also estimated district-specific emissions associated with ocean-going vessel auxiliary engines. The allocation of these estimates is based on the length(s) of United States Army Corps of Engineers shipping lanes associated with a specific district. Table IV-2 presents a district-by-district estimate of emissions from ocean-going vessel auxiliary engines.

Table IV- 2: Estimated 2004 Ocean-going Vessel Auxiliary Engine Emissions By District (tpd)[3]

District	NOx	HC	CO	PM	SOx
Bay Area	7.37	0.21	0.55	0.66	4.81
Mendocino	0.85	0.02	0.06	0.08	0.58
Monterey Bay	1.40	0.04	0.10	0.13	0.95
North Coast	1.47	0.04	0.11	0.13	1.00
Northern Sonoma	0.39	0.01	0.03	0.04	0.27
San Diego	5.50	0.16	0.42	0.53	3.83
San Joaquin Valley	0.39	0.01	0.03	0.03	0.23
San Luis Obispo	0.78	0.02	0.06	0.07	0.53
Santa Barbara	2.96	0.08	0.22	0.27	1.96
South Coast	21.32	0.59	1.62	1.89	13.78
Ventura	0.98	0.03	0.07	0.09	0.64
Yolo-Solano	0.18	<0.01	0.01	0.01	0.11
Total	43.59	1.21	3.28	3.93	28.69

Note: The following districts had no ocean-going auxiliary engine emissions allocated to them; Amador, Antelope Valley, Butte, Calaveras, Colusa, El Dorado, Feather River, Glenn, Great Basin Unified, Imperial, Kern, Lake, Lassen, Mariposa, Modoc, Mojave Desert, Northern Sierra, Placer, Sacramento, Shasta, Siskiyou, Tehama, and Tuolumne.

Table IV-3 provides estimates of emissions from ocean-going auxiliary engines operating in the proposed regulated waters, which includes all of California's inland waters, estuarine waters, and all waters within 24 nautical miles (nm) of the California coastline. The 24 nm proposed regulatory waters has been designated by ARB staff as the area where the proposed regulation would be enforced. This area is shown in Figure IV-1 as the dark grey area adjoining the California coastline.

[3] The total emissions may vary slightly from the values shown in Table IV-1 due to rounding.

Table IV-3: Estimated 2004 Ocean-going Vessel Auxiliary Engine Emissions Occurring Within the Proposed Regulatory Waters

Vessel Types	2004 Pollutant Emissions, Tons/Day				
	NOx	PM	HC	CO	SOx
Auto	0.90	0.08	0.02	0.07	0.57
Bulk	3.76	0.33	0.10	0.28	2.38
Container	15.71	1.37	0.43	1.19	9.95
General	1.62	0.14	0.04	0.12	1.03
Passenger	8.31	0.80	0.23	0.62	5.89
Reefer	0.59	0.05	0.02	0.04	0.37
RoRo	0.34	0.03	0.01	0.03	0.21
Tanker	2.24	0.19	0.06	0.17	1.42
Totals	33.47	2.99	0.91	2.52	21.82

Projected 2010 and 2020 Emission Estimates for Ocean-going Vessel Auxiliary Engines

The projected emission estimates for the years 2010 and 2020 are presented in Table IV-4. As discussed in the methodology included in Appendix D, the vessel type-specific ocean-going vessel growth estimates were developed based upon historical data of the installed power of the propulsion engines of ocean-going vessels from 1997 to 2003. The vessel type-specific growth rates developed were the midpoint between the best fit compounded growth rate for the seven data points and the best fit linear (arithmetic) growth rate for the same data.

The port specific growth rates were applied to in-port emissions: hotelling and maneuvering and in-transit emissions within 3 nm of the coast of the California mainland. In-transit emissions that occur in the outer continental shelf (beyond the 3 nm limit) cannot be tied directly to a single port; as a result, vessel type-specific growth factors are used. The vessel type specific growth factors are also used where port specific factors are not available, such as passenger vessels calling on Monterey. Details on the growth assumptions are provided in Appendix D.

Expected emission reductions and the impact on the ocean-going vessel auxiliary engine emission estimates are discussed in Chapter VII, Environmental Impacts.

Table IV-4: Ocean-going Vessel Auxiliary Engine Projected Year 2010 and 2020 Emission Estimates

Vessel Types	2010 Emission, Tons per Day					2020 Emission, Tons per Day				
	NOx	HC	CO	PM	Sox	NOx	HC	CO	PM	SOx
Auto	1.35	0.04	0.10	0.12	0.86	2.63	0.07	0.20	0.23	1.67
Bulk	5.40	0.15	0.41	0.47	3.42	8.34	0.23	0.63	0.73	5.28
Container	23.22	0.64	1.76	2.02	14.72	33.71	0.93	2.55	2.93	21.37
General	2.36	0.07	0.18	0.21	1.50	4.42	0.12	0.33	0.38	2.80
Passenger	14.99	0.41	1.13	1.44	10.63	40.26	1.10	3.03	3.88	28.55
Reefer	0.86	0.02	0.07	0.08	0.55	1.27	0.03	0.10	0.11	0.81
RoRo	0.49	0.01	0.04	0.05	0.31	0.71	0.02	0.05	0.06	0.45
Tanker	2.99	0.08	0.23	0.26	1.89	4.09	0.11	0.31	0.36	2.59
Totals	51.66	1.42	3.92	4.65	33.88	95.43	2.61	7.20	8.68	63.52

B. Transport of Offshore Ocean-going Vessel Emissions to Onshore

The transport of air pollution over long distances and between air basins has been well established. The emissions from ocean-going vessels can travel great distances and numerous studies have shown local, regional, and global impacts on air quality. (Endresen, 2003; Jonson, 2000; Corbett and Fishbeck, 1997; Streets, 2000; Saxe and Larsen, 2004) Tracer studies, air quality modeling, and meteorological data analysis are typical approaches used to determine the extent to which emissions released offshore can impact onshore areas. Several studies support ARB staffs conclusion that emissions from ocean-going vessels released offshore the California Coast can impact onshore air quality. These studies are briefly described below and provided in additional detail in Appendix F.

A tracer study involves the release of a known amount of a non-toxic, inert gas such as sulfur hexafluoride and perfluorocarbon, from either a moving or fixed point offshore and the subsequent sampling of the atmosphere for concentrations of that gas at sites onshore. In California, there have been three tracer studies conducted to investigate the effect of offshore vessel emissions on onshore air quality (Chen, 2005; ARB, 1982; ARB, 1983; ARB, 1984). The tracer gases were released from 8 to over 20 miles offshore. All three studies resulted in tracer gases being detected at onshore sampling stations spanning over wide distances. From these studies we can infer that pollutants emitted from offshore vessels can be transported to onshore areas and be available to participate in onshore atmospheric processes, influencing onshore air quality.

The onshore impacts of offshore emissions have also been investigated using air quality modeling. A modeling study conducted by the Department of Defense has concluded that the emissions released within 60 nautical miles offshore in the southern California coastal region could transport to the coast (ARB, 2000). Another modeling study conducted by the U. S. Navy using 10 years of hourly surface wind data to estimate the probability that offshore emissions would impact land from specified distances has shown that for California, the probabilities of offshore emissions being transported to the coast within 96 hours were greater than 80 percent from 50 nautical miles offshore (Eddington, 1997).

The U.S. EPA has set a 175 nautical mile boundary off from the United States coasts for development of vessel NOx emission inventory (Eddington, 2003; EPA, 2003). The 175-mile area is based on the estimate of the distance a NOx molecule could travel in one day (assuming a 10 mile per hour wind traveling toward a coast, NOx molecules emitted 12 miles from the coast could reach the coast in just over one hour. NOx molecules emitted 175 nautical miles (200 miles) could reach the coast in less than a day). ARB has also conducted studies on the onshore impact of offshore emissions. ARB's studies have demonstrated that pollutants released off California's coast can be transported to inland areas due to the meteorological conditions off the coast (Chen, 2005; ARB, 1982; ARB, 1983; ARB, 1984).

There has been very little actual in-transit measurement of the pollutant emissions from ships to better understand various aspects of vessel plume chemistry and reconcile differences between measurements and model predictions. However, a recent study conducted by Chen et al (Chen, 2005), in which measurements of chemical species in vessel plumes were taken from aircraft transecting a vessel plume, indicates that the NOx half-life within a vessel's plume may be much shorter than predicted by photochemical models. The study demonstrated a NOx lifetime of about 1.8 hours inside the vessel plume at noontime as compared to about 6.5 hours in the background marine boundary layer of the experiment. Additional studies investigating vessel plume chemistry will help us better understand vessel plume chemistry and improve the photochemical models used to investigate the impacts of vessels on air quality.

The analysis of meteorological data can also be used to demonstrate that emissions released offshore can reach onshore airsheds. In 1983, the ARB established the California Coastal Waters (CCW) boundary, based on coastal meteorology, within which pollutants released offshore would be transported onshore. The development of the boundary was based on over 500,000 island, ship-board, and coastal observations from a variety of records, including those from the U.S. Weather Bureau, U.S. Coast Guard, Navy, Air Force, Marine Corps, and Army Air Force (ARB, 1982). The CCW boundary ranges from about 25 miles off the coast at the narrowest to just over 100 miles at the widest.

C. Potential Exposures and Health Risks from Ocean-going Vessel Auxiliary Engine Diesel PM Emissions

This section examines the exposures and potential health risks associated with particulate matter (PM) emissions from auxiliary engines on ocean-going vessels. A brief qualitative discussion is provided on the potential exposures of Californians to the diesel PM emissions from ocean-going vessel auxiliary engine operations. In addition, a summary is presented of a health risk assessment conducted to determine the 70-year potential cancer risk associated with exposures to diesel PM emissions from ocean-going vessel auxiliary engines associated with operations at the Ports of Los Angeles and Long Beach. The ARB staff believes that the results from this analysis provide quantitative results for exposures around the Ports of Los Angeles and Long Beach and are generally applicable to other ports in California, providing a qualitative estimate for those areas.

Exposures to Diesel PM

As discussed previously, ocean-going vessels visit California ports and travel in waters along the coastline of California and within certain inland waterways. The diesel PM emissions from auxiliary engines contribute to ambient levels of diesel PM emissions. Based on the most recent emissions inventory, there are about 10,000 visits to California ports by ocean-going vessels that have auxiliary engines. The majority of ports are in urban areas and, in most cases, are located near where people live, work, and go to school. This results in substantial exposures to diesel PM emissions from the operation of vessel auxiliary engines. Because analytical tools to distinguish between ambient diesel PM emissions from vessel auxiliary engines and that from other sources of diesel PM do not exist, we cannot measure the actual exposures to emissions from diesel-fueled vessel auxiliary engines. However, modeling tools can be used to estimate potential exposures.

To investigate the potential risks from exposures to the emissions from auxiliary engines, ARB staff used dispersion modeling to estimate the ambient concentration of diesel PM emissions that result from the operation of ocean-going vessel auxiliary engines that visit the Ports of Los Angeles and Long Beach. The potential cancer risks from exposures to these estimated ambient concentrations of diesel PM were then determined. The results from this study are presented below, and additional details on the methodology used to estimate the health risks are presented in Appendix G.

Health Risk Assessment

Risk assessment is a complex process that requires the analysis of many variables to simulate real-world situations. There are three key types of variables that can impact the results of a health risk assessment for cargo handling equipment: the magnitude of diesel PM emissions, local meteorological conditions, and the length of time of exposure. Diesel PM emissions are a function of the age and horsepower of the engine, the emissions rate of the engine, and the annual hours of operation. Older engines tend to have higher pollutant emission rates than newer engines, and the longer an engine operates, the greater the total pollutant emissions. Meteorological conditions can have a large impact on the resultant ambient concentration of diesel PM, with higher concentrations found along the predominant wind direction and under calm wind conditions. How close a person is to the emissions plume and how long he or she breathes the emissions (exposure duration) are key factors in determining potential risk, with longer exposures times typically resulting in higher risk.

To examine the potential health risks for ocean-going vessel auxiliary engines, ARB staff conducted a risk assessment for operations at the Ports of Los Angeles and Long Beach. We evaluated the impacts from the 2002 estimated emissions for all sources of emissions at the two ports including ocean-going vessel auxiliary engines. Meteorological data from Wilmington was used for the study. The Wilmington site is about one mile away from the ports, and the measurements were collected in 2001. The U.S. EPA's ISCST3 air dispersion model was used to estimate the annual average offsite concentration of diesel PM in the area surrounding the two ports. The modeling domain (study area) spans a 20 x 20 mile area, which includes both the ports, the ocean surrounding the ports, and nearby residential areas in which about 2 million people live. The land-based portion of the modeling domain, excluding the property of the ports, comprises about 65 percent of the modeling domain. A Cartesian grid receptor network (160 x 160 grids) with 200-meter x 200-meter resolution was used in this study. While grids within the ports were included in the network, the risks within these grids were excluded from the final risk analyses. The elevation of each receptor within the modeling domain was determined from the United States Geological Service topographic data.

The potential cancer risks were estimated using standard risk assessment procedures based on the annual average concentration of diesel PM predicted by the model and a health risk factor (referred to as a cancer potency factor) that correlates cancer risk to the amount of diesel PM inhaled. The methodology used to estimate the potential cancer risks is consistent with the Tier-1 analysis presented in the Office of Environmental Health Hazard Assessment (OEHHA) Air Toxics Hot Spots Program Risk Assessment Guidelines (OEHHA, 2002a; OEHHA, 2002b). Following the OEHHA guidelines, we assumed that the most impacted individual would be exposed to modeled diesel PM concentrations for 70 years. This exposure duration represents an "upper-bound" of the possible exposure duration. The potential cancer risk was estimated by multiplying the inhalation dose by the cancer potency factor (CPF) of diesel PM (1.1 $(mg/kg\text{-}d)^{-1}$).

<u>Cancer Risk Characterization</u>

Emissions from vessel auxiliary engines resulted in significant health risk impacts on the nearby residential areas. Figure IV-3 shows the risk isopleths for diesel PM emissions from vessel auxiliary engines (transiting and hotelling) at the Ports of Los Angeles and Long Beach superimposed on a map that covers the ports and the nearby communities.

As shown in Figure IV-3, the area in which the risks are predicted to exceed 100 in a million has been estimated to be about 13,500 acres with a population of 225,100. For the risk level of over 200 in a million, the impacted areas have been estimated to be about 2,260 acres and about 48,000 people living around the ports who are exposed to the risk level. Overall, about 99.5 percent of the effective modeling domain (excluding the port property and the surrounding ocean area) has an estimated risk level of over 10 in a million and about 99.6 percent of 2 million people who are living in the domain are exposed to the risk level (see Table IV-5).

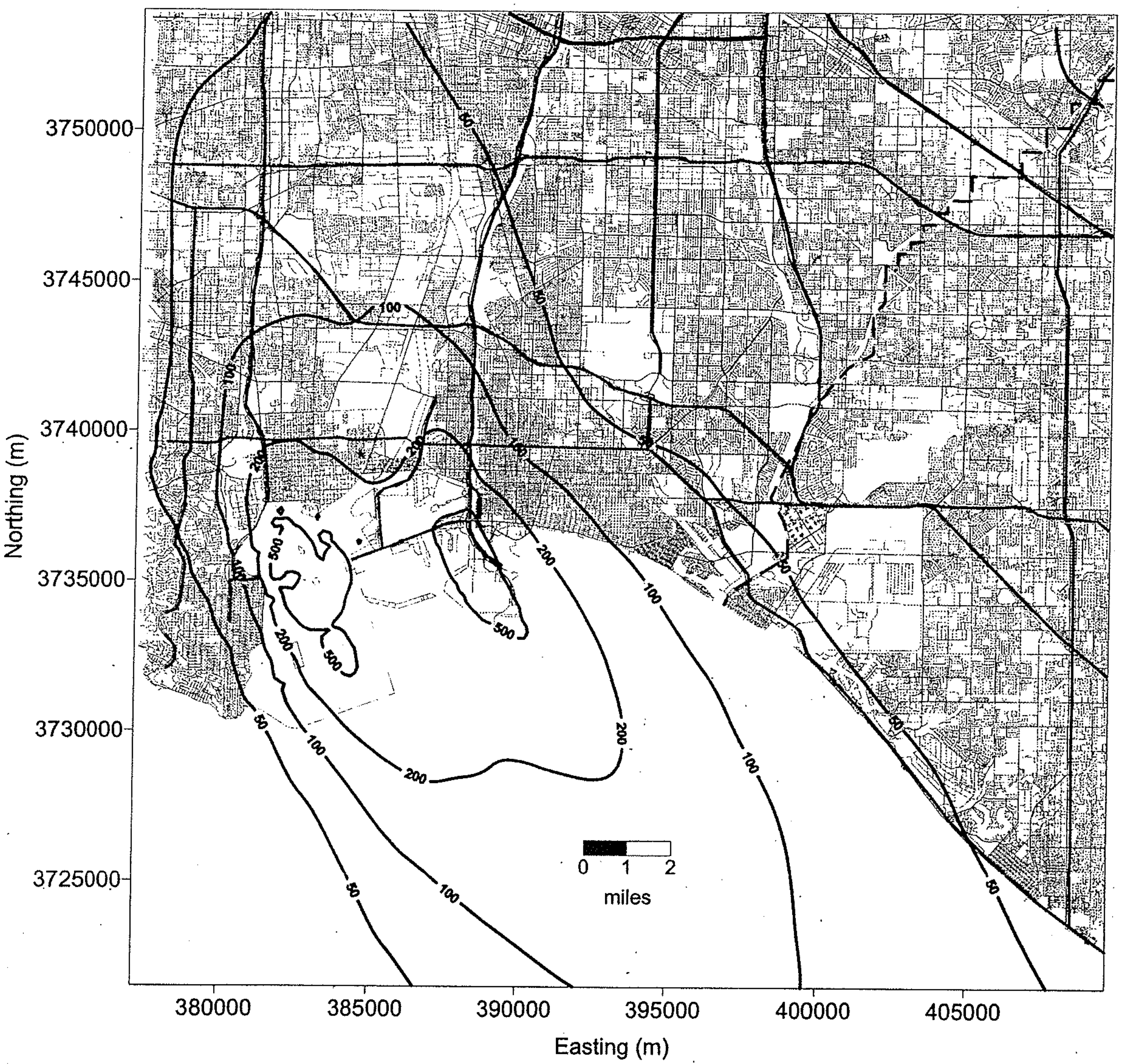
Using the U.S. Census Bureau's year 2000 census data, we estimated the population within the isopleth boundaries. The acres impacted and population affected for the risk ranges of 10-100, 100-200, 200-500, and over 500 are presented in Table IV-5. As shown in Table IV-5, nearly 2 million people living in the area around the ports have a predicted cancer risk of greater than 10 in a million due to emissions from auxiliary engines. Note that the size of the modeling domain was limited by the technical capabilities of the model. However it is clear that a significant number of people outside the modeling domain area are exposed to risks greater than 10 in a million.

Table IV-5: Summary of Area Impacted and Population Affected by Risk Levels

Risk Level	Acres Impacted	Population Affected
Risk > 500	0	0
Risk > 200	2,263	47,941
Risk > 100	13,492	225,162
Risk > 10	162,565	1,969,397

Note: The effective modeling domain is the land area outside of port property, and is about 255 square miles or 163,435 acres. The total population within the domain is about 2 million.

Figure IV-3: Estimated Diesel PM Cancer Risk from Ocean-going Vessel Auxiliary Engine Activity at POLA and POLB



Parameters: Wilmington Met Data
Urban Dispersion Coefficients
80th Percentile Breathing Rate
Emission = 405 TPY
Modeling Receptor Domain = 20 mi x 20 mi
Resolution = 200 m x 200 m

Non-Cancer Health Risks

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter and adverse health effects. (CARB, 2002) As part of this study, ARB staff conducted an analysis of the potential non-cancer health impacts associated with exposures to the model-predicted ambient levels of directly emitted diesel PM (primary diesel PM) discussed above and extrapolated them to the rest of the state. The non-cancer health effects evaluated include premature death, asthma attacks, work loss days, and minor restricted activity days.
Based on our analysis, we estimate that the average number of cases statewide in 2004 due to emissions from auxiliary engines would be as follows:

- 31 premature deaths (for ages 30 and older), 16 to 48 deaths as 95% confidence interval (CI);
- 830 asthma attacks, 202 to 1, 457 as 95% CI;
- 7,258 days of work loss (for ages 18-65), 6,143 to 8,370 as 95% CI;
- 38,526 minor restricted activity days (for ages 18-65), 31,403 to 45,642 as 95% CI.

As stated previously, to estimate these statewide potential non-cancer health impacts from auxiliary engine emissions, ARB staff estimated the non-cancer health impacts from ocean-going vessel auxiliary engine emissions in the area surrounding the ports of Los Angles and Long Beach and extrapolated these results to predict statewide values based on the ratio of the mass emissions at the POLB and POLA to those in the rest of the State. A brief discussion on the methodology used to generate these estimates is provided below.

Non-Cancer Health Effects Methodology

ARB staff assessed the potential non-cancer health impacts associated with exposures to the model-predicted ambient levels of directly emitted diesel PM (primary diesel PM) within each 200 meter by 200 meter grid cell within the modeling domain used for the POLA-POLB exposure assessment study. Because the study used the 2002 emissions estimates for auxiliary engine emissions at the ports, the ambient concentrations were adjusted to reflect the updated 2004 emissions inventory developed by ARB staff. The populations within each grid cell were determined from U.S. Census Bureau year 2000 census data. Using the methodology peer-reviewed and published in the Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates (PM Staff Report; CARB, 2002), we calculated the number of annual cases of death and other health effects associated with exposure to the ambient PM concentrations modeled for each of the grid cells. For each grid cell, each health effect was estimated based on concentration-response functions derived from published epidemiological studies relating changes in ambient concentrations to changes in health endpoints, the population affected, and the baseline incidence rates. The total affected population was obtained by summing the results from each grid cell.

The selection of the concentration-response functions was based on the latest epidemiologic literature, as described in the PM Staff Report (ARB, 2002) and in Lloyd and Cackette (Lloyd and Cackette, 2001). Staff estimated that the ports of Los Angeles and Long Beach account for approximately 48% of total statewide emissions related to auxiliary engine activities. Hence, the statewide impact of the auxiliary engine emissions was estimated by dividing the estimated impacts in the modeling domain around the ports of Los Angeles and Long Beach by 0.48.

Several assumptions were used in quantifying the health effects of PM exposure. They include the selection and applicability of the concentration-response functions, exposure estimation, subpopulation estimation, baseline incidence rates, and the extrapolation from results in the modeling domain to the statewide results. These are briefly described below.

- Premature death calculations were based on the concentration-response function of Krewski et al. (Krewski et al, 2000) The ARB staff assumed that concentration-response function for premature mortality in the model domain is comparable to that in the Krewski study. It is known that the composition of PM can vary by region, and not all constituents of PM have the same health effects. However, numerous studies have shown that the mortality effects of PM in California are comparable to those found in other locations in the United States, justifying our use of Krewski et al's results. Also, the U.S. EPA has been using Krewski's study for its regulatory impact analyses since 2000. For other health endpoints, the selection of the concentration-response functions was based on the most recent and relevant scientific literature. Details are ARB's PM Staff Report (ARB, 2002).

- The ARB staff assumed the model-predicted exposure estimates could be applied to the entire population within each modeling grid. That is, the entire population within each modeling grid of 200 meter x 200 meter was assumed to be exposed uniformly to modeled concentration. This assumption is typical of this type of estimation.

- The ARB staff assumed the grid cell population had similar age distributions as the county in which it was located. The subpopulation used for each health endpoint was calculated by multiplying the all-age population for each grid cell by the county-specific ratio of the subpopulation used for the endpoint over the all-age population. For example, mortality estimates were based on subpopulations age 30 or more estimated from ratios of people over 30 over the entire population, specific for each county. For Los Angeles County, this value was 54 percent. These estimates were needed because information on the particular subpopulation in each modeling grid was not available.

- The ARB staff assumed the baseline incidence rates were uniform across each modeling grid, and, in many cases, across each county. This assumption is consistent with methods used by the U.S. EPA for its regulatory impact assessment. The incidence rates match those used by U.S. EPA.

- Because only impacts from directly emitted diesel PM are estimated and a subset of health outcomes is considered here, the estimates should be considered an underestimate of the total public health impact. In addition, the model domain for the study was 20 miles by 20 miles and did not capture all of impacts on the surrounding communities from the POLA and POLB emissions.

- Without readily available modeled concentrations at other ports in California, staff extrapolated the results based on the modeling domain around ports of Los Angeles and Long Beach to infer statewide effects. In doing so, we assumed that the population density and the change in concentrations due to the regulation would be similar to those in the ports of Los Angeles and Long Beach.

REFERENCES

(ARB, 1983) California Air Resources Board, *Report to the California Legislature on Air Pollutant Emissions from Marine Vessels, Volume 1*, June 1983.

(ARB, 1982), California Air Resources Board, *Air Quality Aspects of the Development of Offshore Oil and Gas Resources,* February 25, 1982.

(ARB, 1984) California Air Resources Board, *Report to the California Legislature on Air Pollutant Emissions from Marine Vessels*, Appendices H to M, Volume VI1, June 1984.

(ARB, 2000) California Air Resources Board, et al , *Air Quality Impacts from NOx Emissions of Two Potential Marine Vessel control Strategies in the South Coast Air Basin.*, November 2000.

(ARB, 2002) California Air Resources Board and Office of Environmental Health Hazard Assessment. Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates, available at http://www.arb.ca.gov/research/aaqs/std-rs/pm-final/pm-final.htm. 2002.

(Chen, 2005) Chen, G. et al., 2005, *"An Investigation of the Chemistry of Ship Emission Plumes during ITCT 2002,"* J. of Geophysical Research, 110, D10S90, doi:10.1029/2004JD005236.

(Corbett and Fishbeck, 1997) Corbett, J.J. and Fishbeck, Paul, "*Emissions from Ships*", Science, Vol 278, 1997.

(Eddington, 1997) Eddington, Lee, et al., *"A Review of Meteorological Studies Pertaining to Southern California Offshore Ship Emissions And Their Effect on the Mainland*", Geophysics Branch, Naval Air Warfare Center Division, Point Mugu, CA, Geophysical Sciences Technical Note No. 200., February 1997.

(Eddington, 2003) Eddington, Lee and Rosenthal, Jay, *"The Frequency of Offshore Emissions Reaching the continental UW Coast Based on Hourly Surface Winds from a 10 Year Mesoscale Model Simulation"*, Geophysics Branch Technical Note. March 2003.

(Endresen, 2003) Endresen, O., et al, "*Emission from international Sea Transportation and Environmental Impact*", Journal of Geophysical Research, 108, 2003.

(EPA, 2003) United States Environmental Protection Agency, *Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder*, January 2003.

(Jonson, 2000) Jonson, Jan E., et al, "*Effects of International Shipping on European Pollution Levels*", Norwegian Meteorological Institute, Research Report 41, July 2000.

(Krewski et al. 2000) Krewski D.; Burnett R.; Goldberg M.; Hoover K.; Stemiatychi J.; Jerrett M.; Abrahamovicz M.; White W. Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality, Health Effects Institute, Cambridge, Massachusetts; 2000. http://es.epa.gov/ncer/science/pm/hei/Rean-ExecSumm.pdf

(Lloyd and Cackette. 2001) Lloyd, A.C.; Cackette, T.A.; Diesel Engines: Environmental Impact and Control; J Air Waste Manage. Assoc. 2001, 51: 809-847.
http://www.arb.ca.gov/research/seminars/lloyd/AWMA2001/JAWMADieselCritical Review.pdf

(OEHHA. 2002a) *Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments.* Office of Environmental Health Hazard Assessment. June, 2002.

(OEHHA. 2002b) *The Air Toxics Hot Spot Program Risk Assessment Guidelines: Part II-Technical Support Document for Describing Available Cancer Potency Factors.* Office of Environmental Health Hazard Assessment. June, 2002.

(Saxe and Larsen, 2004) Saxe, H. and Larsen, T., "*Air Pollution from Ships in Three Danish Ports*," Atmospheric Environment, 38, 4057-4067, 2004.

(Streets, 2000) Streets, D.G., "*The Growing Contribution of Sulfur Emissions from Ships in Asian Water, 1988-1995*", Atmospheric Environment, 34, 4425-4439, 2000.